Sustainable, Affordable Cooling Can Save Tens of Thousands of Lives Each Year

International Energy Agency

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Abstract

Energy demand for space cooling has increased more than twice as fast as the overall energy demand in buildings over the last decade. Higher temperatures caused by climate change, coupled with increasing incomes and growing populations, are driving rapid growth in residential air conditioning (AC) ownership.

Yet, of the 3.5 billion people who live in hot climates, only about 15% owned AC in 2021, with even lower ownership levels in Sub-Saharan Africa and South Asia. Lack of access to indoor cooling puts much of the global population at high risk for heat stress, adversely affecting thermal comfort, labour productivity, and human health. Between 2002-2004 and 2019-2021, the average annual number of heat-related deaths among people aged 65 years or older increased by 61%, reaching an estimated 300 000 or more deaths.

Nevertheless, access to effective cooling has saved tens of thousands of lives; over the same period, the average annual number of heat-related deaths averted by AC increased 3-fold, reaching an estimated 190 000 lives saved per year during 2019-2021.

However, the rapid growth of AC is putting stress on the power grid, whilst exacerbating the adverse impact of space cooling on GHG emissions, local air pollution, power outages, urban heat island effects, energy poverty, and physiological acclimatisation.

This analysis examines available technical and policy response measures that are a win-win: they can ensure that lower income households are not left behind, and that growth in space cooling does not cause harm to the climate and health.

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Keeping people cool can save tens of thousands of lives each year. But it must be efficient, affordable and resilient

In many parts of the world, this winter's energy crisis posed challenges to people keeping warm in their homes, especially for low-income households. This follows a year in which large portions of the globe suffered from unprecedented climate change-driven heat waves, with record high temperatures in Japan, Europe, North Africa, the Middle East, India, Pakistan, China, North America, South America, and Australia. Hundreds of millions of people struggled with an urgent need to keep their homes cool in the face of high energy prices and/or lack of access to effective cooling solutions. Staying warm during winter and cool during summer is not only a matter of comfort: it's also essential for health. The hot and cold seasons over the past year or so have highlighted the critical importance of universal access to efficient, affordable, and resilient heating and cooling for public health. In this analysis, in anticipation of more record hot temperatures, we focus on cooling.

Over the last decade, energy demand for space cooling increased more than twice as fast as the overall energy demand in buildings

Over the centuries, people have developed a broad range of approaches to staying cool during hot weather. These span the individual, household and community levels, and both passive (approaches that do not require energy) and active (approaches that require energy) solutions (see Table 1 for contemporary solutions). For example, traditional architecture in tropical and sub-tropical climates has used passive cooling approaches including shading (e.g. verandas), cross-ventilation (e.g. windows or other openings on opposite walls), and light-coloured building materials that reflect the rays of the sun.

Passive cooling solutions are preferable for protecting the climate, conserving energy, and keeping energy costs low. However, in many parts of the world, active solutions such as fans (a low-energy-consumption solution), and air conditioning (AC, a higher-energy-consumption solution), now represent the primary approaches to space – or indoor – cooling.

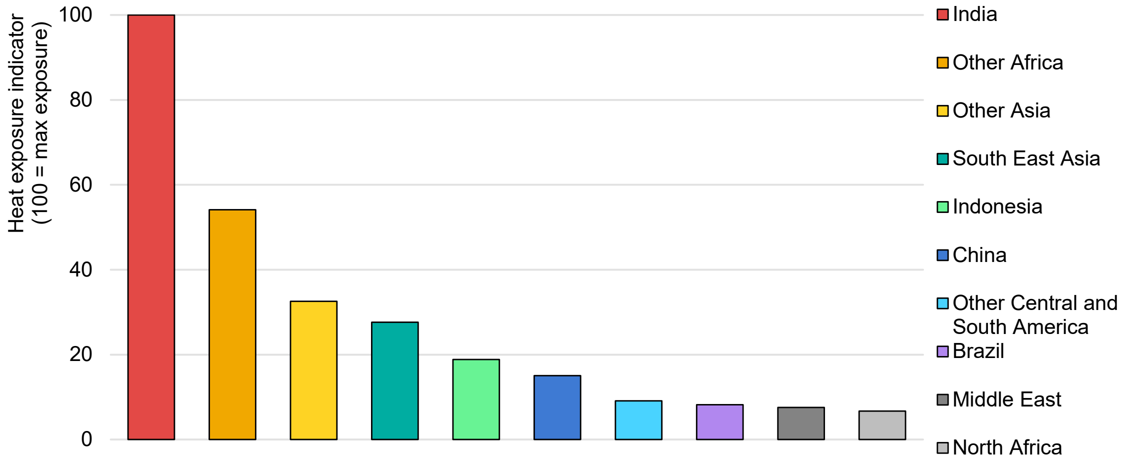
Higher temperatures caused by climate change, coupled with increasing incomes and growing populations, are driving rapid growth in residential AC ownership, with about 1.5 billion units installed worldwide by the end of 2021. Globally households with AC increased from about 25% in 2010 to about 35% in 2021. Between 2020 and 2021, space cooling energy consumption increased by more than 6%, greater than any other building end use, with growth close to 8-9% in Asia Pacific and Europe.

Gaps in access to effective cooling have implications for thermal comfort, productivity and health

Yet, of the 3.5 billion people who live in hot climates,[1] only about 15% owned AC in 2021, with even lower ownership levels in Sub-Saharan Africa and South Asia. In addition, most buildings in these areas are not equipped with sufficient passive or low-energy-consumption cooling solutions. An estimated 2-4 billion people in the Global South, or 25-50% of the world's population, are potentially exposed to heat stress due to lack of effective indoor cooling. In particular, AC is unavailable to households with no electricity and remains unaffordable for many low-income households with electricity. Even households that can afford the initial investment in AC often cannot afford the electricity bills associated with its operation.

Lack of access to indoor cooling puts a very large part of the population in the Global South at high risk for heat stress, adversely affecting thermal comfort, labour productivity, and human health.

Figure 1. Population-weighted heat stress exposure, top ten countries/regions, 2021



Note: This indicator was derived by multiplying population, cooling degree days calculated at base temperature 18°C, and (1 minus the proportion of households with AC) for each region or country. Cooling degree days are the difference between the daily temperature mean (when it is above the reference temperature) and a certain reference temperature (18°C in this case). To take the impact of relative humidity on perceived temperature into account, heat index was used for calculating this indicator. 100 corresponds to the maximum value of the indicator. 18°C does not represent the indoor temperature set point but rather is used for the sole purpose of comparing across countries/regions.

Other Africa excludes South Africa and North Africa; Other Asia excludes China India, Indonesia, Japan, South Korea; and South East Asia; South East Asia includes Brunei Darussalam, Cambodia, Lao People's Democratic Republic, Malaysia, Myanmar, Philippines, Pitcairn, Singapore, Thailand, and Vietnam; Other Central and South America excludes Brazil, Chile, Colombia; and Mexico; Middle East includes Islamic Republic of Iran, Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, and Yemen: North Africa includes Algeria, Egypt, Libya, Morocco, and Tunisia.

Source: climate data from IEA (2022), Weather for Energy Tracker, IEA, Paris https://www.iea.org/data-and-statistics/data-tools/weather-for-energy-tracker; other data from IEA modelling.

[1] A climate is assumed to be "hot" when the sum total of the difference between the daily mean outdoor temperature (when it is above the base temperature) and the base temperature of 10°C adds up to at least 5 000 over the course of one year. See IEA (2020), Is Cooling the Future of Heating? (10°C does not represent the indoor temperature set point, but is rather used for the sole purpose of comparing across countries). This definition refers to hot and humid climates and other areas with very high cooling needs as highlighted in the IEA World Energy Outlook 2022.

When exposed to excessive heat, the human thermoregulatory system, including sweating for evaporative cooling and increased skin blood flow for transfer of heat away from the skin, can become impaired or fail, leading to heat-related illness or even death. Heat can cause heat exhaustion or heat stroke (a medical emergency that is often fatal); can trigger acute health events, including acute kidney failure and heart attack; and can exacerbate pre-existing chronic diseases, such as heart or lung disease.

There are a number of risk factors for heat-related illness that make people more vulnerable to rising temperatures and extreme heat events. Older populations and people with chronic disease are particularly at risk, as are homeless people, people who work outdoors, and those who live in inadequate (e.g. poorly insulated) housing. Some areas within cities are particularly hot due to especially dense urban infrastructure, a high volume of automobile traffic, and lack of green space (such as parks, gardens, trees, and shrubs) and blue space (such as bodies of water including lakes, rivers, and ponds).

Risk factors also include lack of mobility, social isolation, and – importantly – lack of access to effective indoor cooling. AC, currently the most widespread effective cooling solution, can be used as a proxy for assessing the effectiveness of indoor cooling in general. Epidemiologic studies have shown that AC is highly protective against heat-related death: in fact, the risk among people with household AC is about a quarter of the risk among people without household AC.

Access to effective cooling has already saved tens of thousands of lives

The 2021 report of the Lancet Countdown on health and climate change estimated that about 345 000 heat-related deaths occurred globally in 2019 among people aged 65 years or older. Using data provided by the IEA, along with other data, the report also estimated that thanks to AC access, around 195 000 heat-related deaths were averted in this high-risk senior and elderly population in the same year. New analyses show that in this population, between 2002-2004 and 2019-2021, the average annual number of heat-related deaths increased by 61% to 316 000, and that the average annual number of heat-related deaths averted by AC increased 3-fold to 191 000.[2]

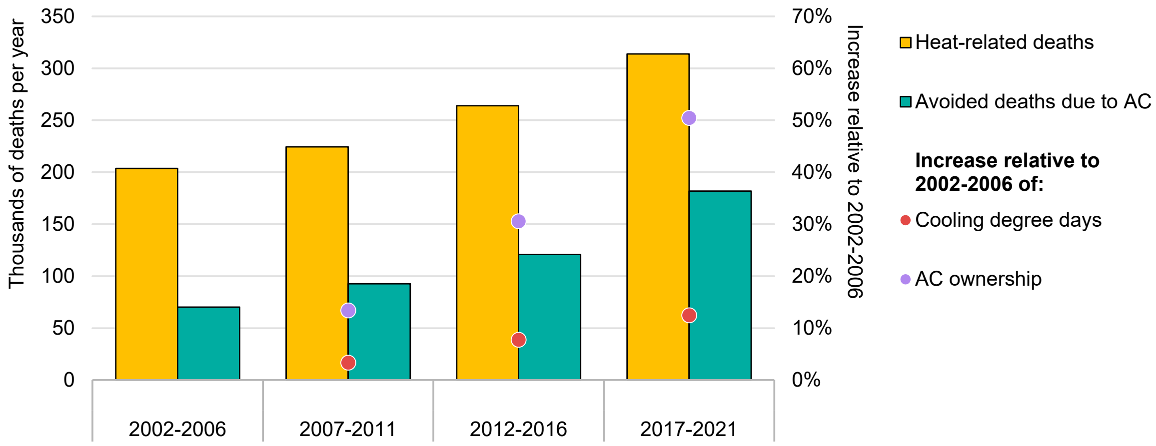
Estimating global heat-related deaths and deaths averted by AC pose data availability and methodological challenges, but it is clear that each year hundreds of thousands of people die from heat, and that AC helps avoid tens of thousands of additional deaths.

[2] The annual average of 191,000 heat-related deaths averted by AC during 2019-2021, previously unpublished, was estimated using the same method used for the 2019 estimate in the 2021 *Lancet* Countdown report.

The potential to save even more lives is evident when comparing countries with high and low AC ownership. For example, among people aged 65 years or older in Japan, where more than 90% of households had AC in 2019-2021, we estimated that 32 500 heat-related deaths per year were averted thanks to AC. In India, where fewer than 10% of households had AC, we estimated that 2 200 heat-related deaths per year were averted by AC over the same period[3].

Effective cooling saves lives, whether through AC or more sustainable, lower-energy-consumption approaches. In the remainder of this document, we discuss the sustainability challenges associated with AC and the promise of alternative cooling solutions that, if adopted widely, can provide effective cooling whilst substantially reducing energy demand for AC.

Figure 2. Global heat-related deaths and deaths avoided in individuals aged 65 years or older due to AC, 2002-2021, and percentage increase of cooling degree days and household AC ownership over 2002-2006 average



Note: Cooling degree days are the difference between the daily temperature mean (when it is above the reference temperature) and a certain reference temperature (18°C in this case). To take the impact of relative humidity on perceived temperature into account, the heat index was used to calculate cooling degree days in this graph.

Sources: IEA (2022), Weather for Energy Tracker, IEA, Paris https://www.iea.org/data-and-statistics/data-tools/weather-for-energy-tracker (cooling degree days); IEA modelling (AC ownership); The 2022 report of the Lancet Countdown on health and climate change: health at the mercy of fossil fuels (for heat-related deaths); and previously unpublished results (for deaths averted due to AC).

Access to effective cooling does not need to come at the cost of the environment or health

With rising incomes and a hotter climate, global household AC ownership is projected to reach 45% by 2030 – up from 35% in 2021. This is good news for protecting against heat-related illness and mortality, but uncontrolled growth and use of AC could exacerbate related climate and health harms, including:

[3] Note that there are many differences between Japan and India including a much older age distribution in Japan.

- Greenhouse gases (GHGs) and air pollution from fossil fuel combustion in power generation: in 2021, space cooling accounted for about a gigatonne of related CO_2 emissions from the power sector. The 2021 Lancet Countdown report, using IEA and other data, estimated that fine particulate matter (i.e. $PM_{2.5}$) pollution from fossil fuel combustion to power AC was responsible for 24 000 deaths globally in 2020.
- GHGs from hydrofluorocarbon (HFC) refrigerants: HFCs used in AC are powerful GHGs and can have high Global Warming Potential (GWP) when they escape into the atmosphere. The 2016 Kigali Amendment to the Montreal Protocol, ratified by 148 countries as of 1st March 2023, mandates a reduction of the production and consumption of HFCs by more than 80% by 2047.
- Power outages in areas with high AC use: on hot days, space cooling can account for as much as half of peak electricity demand or more. This can lead to power outages, which in turn increase the risk of heat-related illness and death due to lack of indoor cooling and broken cold chains in the food and health sectors. Outages can also result in carbon monoxide poisoning, gastrointestinal illness, and sickness due to failure of electrical-powered medical equipment.
- Urban heat islands: AC expels heat from the indoor to the outdoor environment. In cities with high AC use, this heat can increase outdoor night-time temperatures by more than 1˚C, exacerbating the nocturnal heat island effect and leading to increased risk for heat-related illness and death.
- Energy poverty: AC use adds to electricity bills, potentially forcing low-income households into energy poverty and the choice between staying cool or paying for other necessities. The costs of installing more efficient AC equipment or making building improvements (e.g. with insulation) can be unaffordable for low-income households, creating a situation of ongoing high energy bills that make it difficult to leave energy poverty.
- Weak physiological acclimatisation: our bodies adapt (acclimatise) to heat exposure through mechanisms such as an increased sweat rate, reduced loss of sodium from sweat, increased rate of skin blood flow, and expansion of blood volume. Over-cooling (i.e. below recommended thermal comfort levels) with AC, which is quite common, interferes with this acclimatisation, making people more susceptible to heat stress when they go outdoors on a hot day or if their AC fails.

The rapid growth of AC calls for solutions to limit these risks.

A suite of technical and policy solutions can deliver efficient, climate friendly, and health-promoting cooling to all who need it.

The IEA's Net Zero Emissions by 2050 Scenario lays out a pathway towards net zero CO_2 emissions at the global level by 2050 while providing universal energy access and ensuring affordable energy supply. It sets three space cooling-related goals for 2030. Firstly, 20% of total existing building floor area globally and all new building construction are made zero-carbon-ready by 2030. Secondly, AC temperature set-points are moderated in the range of 24-25°C; and, thirdly, the average efficiency rating of new AC equipment is increased by at least 50% in all markets by 2030. This target is achievable with stronger market signals through more stringent, enforced Minimum Energy Performance Standards (MEPS) and buildings energy codes, and through greater international collaboration. Implementing these measures would limit the growth of global electricity demand for space cooling between 2021 and 2030 to 10%, compared to 40% growth without these measures.

Additional high-priority measures to reduce AC energy demand include nature-based solutions (such as green and blue space), high-albedo (i.e. high ability to reflect the sun's rays) streets and sidewalks, and advanced building design (such as high-albedo or green roofs, low-emissivity windows, and suitable insulation). AC sustainability can also be improved through proper installation, maintenance, and end-of-life material management, particularly for GHG refrigerants.

Accelerated efforts to decarbonise power generation with clean energy sources are fundamental to reducing the negative impacts of AC. These energy sources are already economically competitive and are being deployed throughout the world. Almost 30% of electricity was generated using renewable sources in 2021 (of which about 35% was from solar photovoltaics and wind). Decarbonisation is not only a climate imperative (along with a shift toward low- or zero-GWP refrigerants), but will also eliminate emission of toxic air pollutants – most notably fine particulate matter – from the power sector, and increase overall system resilience against price shocks.

Table 1. Technical response measures to the challenges associated with AC growth and heat-related illness and death

Technical solutions	Benefits	Detailed measures	Availability	Affordability
High performing equipment, buildings, and districts	• Reduction of GHG and air pollution (lower energy consumption and shift to low GWP or natural refrigerants) • Lower risk of power outages (peak reduction)	• **Passive solutions: reducing energy service demand**		
		○ Building orientation and layout: shelters/shadings, building insulation, reflective roofs, ventilated roofs, low-emissivity windows, etc.	●	●

Technical solutions	Benefits	Detailed measures	Availability	Affordability
	• Lower risk of urban heat islands (exhaust heat reduction) • Lower risk of energy poverty (lower energy consumption and smaller equipment size) • Increased acclimatisation (avoided over-cooling)	○ District layout: urban form, urban ventilation, traffic infrastructure, etc.	🟢	🟡
		○ Nature-based solutions: urban vegetation and water sources (i.e. green and blue spaces), green roofs and facades	🟢	🟡
		• **Active solutions: reducing energy consumption, GHGs and/or refrigerant GWP**		
		○ Best-in-class efficient fans*	🟢	🟢
		○ Best-in-class efficient AC	🟢	🟡
		○ Advanced AC technologies: hybrid units (with low GWP refrigerants)	🟡	🟡
		○ Refrigerant-free solutions: desiccants, evaporative cooling with membranes, solid state cooling etc.	🔴	🔴
		○ Efficient district cooling	🟢	🟡
		○ Occupant behaviour: reduced use of appliances/equipment, higher temperature set points	🟢	🟢
		○ Efficient sizing, installation, maintenance, and system management (including reduced refrigerant leakage)	🟢	🟢
Renewable space cooling; system integration and flexibility	• Reduction of GHG and air pollution (integration of renewables) • Lower risk of power outages (self-produced and stored electricity) • Lower risk of urban heat island (shifted loads, waste heat recovery)	• **Integration of renewables**		
		○ Sorption technologies coupled with renewable energy sources such as solar thermal and geothermal	🟡	🟡
		○ Solar PV-powered cooling	🟢	🟡
		• **System integration and flexibility**		
		○ Thermal energy storage/ice storage	🟢	🟢
		○ Activated thermal mass, thermally activated building systems	🔴	🔴
		○ Automatised controls	🟡	🟢

Technical solutions	Benefits	Detailed measures	Availability	Affordability
End-of-life measures	• Indirect reduction of GHG and air pollution (avoided refrigerants and material production)	○ Recycle materials and components (electronic components, steel, copper, aluminium) at end-of-life	/	/
	• Direct reduction of GHG (recover and recycle refrigerants)	○ Refrigerant management best practices	/	/

* Fans can be effective in delivering thermal comfort by accelerating heat loss, and if working in parallel with AC, can also enhance AC efficiency. Fans also represent a first accessible opportunity for people vulnerable to heat. However, the impact of fans is limited in very warm climates with lower humidity, where fan use might be discouraged.

Note: 🟢 Available/Should not encounter affordability issues; 🟡 Still not common practice/might encounter affordability issues; 🔴 Not yet available. The assessment was not done for end-of-life measures as the scope is broader than space cooling only. GWP = Global Warming Potential.

However, sustainable, affordable, resilient, and healthy space cooling for all who need it is as much a political challenge as a technical one. Coherent policy packages, supported by the necessary financing, are needed across local, national, regional, and global jurisdictions. For instance, the need for AC and associated energy demand can be reduced through land use planning and regulations that promote expansion and strategic placement of urban green and blue space, and through strong, enforced building codes for retrofitting existing buildings and for new building construction. Regulation and financing to provide access to collective cooling spaces for people without household AC is also critical to protect the most vulnerable, especially in the developing world.

Policies to improve AC energy efficiency, such as MEPS, can drive major efficiency gains to reduce energy consumption - AC energy performance can be doubled on average with existing technology. MEPS need to go hand-in-hand with proper installation of AC. Consumer engagement, including through product labelling, can encourage consumers to adopt best practices, such as purchasing high-efficiency AC and using higher temperature set points.

Financing is key to achieving sustainable, equitable cooling. On a global scale, financial aid from high-income to low- and middle-income countries is essential, through mechanisms such as the Green Climate Fund. On national and sub-national scales, targeted financing can provide public cooling spaces and help low-income households purchase efficient AC equipment and insulate their homes, thus holding down AC energy costs. Further, market-based approaches for AC solutions, such as Cooling as a Service, can help capture efficiency opportunities and increase deployment of innovative technologies or renewable integration. New market-based approaches or community-based mechanisms for district cooling can lead to other "upstream" system benefits (e.g. off-peak cold production). Finally, education and training of AC equipment installation and maintenance personnel are essential for ensuring equipment is operated at the maximum efficiency and for reducing leakage of GHG refrigerants.

Table 2. Policy response measures to the challenges associated with AC growth and heat-related deaths

Policy solutions	Benefits	Actions
Economic and financial instruments	• Provide low- and middle-income countries with the funding needed for sustainable space cooling for their populations	• Financial aid for sustainable space cooling from high-income countries to low- and middle-income countries using mechanisms such as the Green Climate Fund
	• Deliver economy of scale of advanced cooling equipment	• Implement public procurement for sustainable cooling solutions
	• Exploitation of peak shaving, load shifting, and flexibility potential	• Implement incentives, rebates, and grants for best-in class equipment, maintenance, building retrofits, and innovations in new buildings; in particular targeting lower income households and communities
		• Support utilities to promote innovative business models such as on-bill/on-wage financing and Cooling as a Service, and facilitate the market for energy efficiency services
		• Enable utilities to test market designs that integrate flexibility services with the power system
Public and private support to R&D	• Test and further enhance advanced space cooling solutions to work alone or coupled with other technologies as needed in different contexts	• Governments and private actors to support R&D for climate friendly and health-promoting space cooling units and building components
		• Technology prizes and solution challenges such as Global Cooling Prize, #ThisIsCool Campaign, and the Beat the Heat: Nature for Cool Cities Challenge
Market creation and standards	• Ensure high performance buildings and best construction practices for new buildings and existing buildings that undergo a retrofit	• Governments (national and local) to include requirements for building envelopes, renewables targets, minimum temperature set points, and passive and active efficient space cooling strategies into building energy codes and standards.
	• Progressively increase the average efficiency of available space cooling equipment products	• Governments to deliver enforcement of and compliance with building energy codes
		• Governments to implement MEPS for AC in all countries, increase MEPS stringency over time, and facilitate the market for energy efficiency services
		• Governments to complement MEPS by smart control requirements

Policy solutions	Benefits	Actions
		• Regulation to pre-set set points at temperatures no lower than 24-25°C as default options
		• Governments to promote harmonisation of testing procedures and standards across countries, in line with evolving AC operating conditions
Cooperation-based instruments	• Catalyse cost reductions from technology advances • Share best practices, knowledge, and expertise	• Governments and all stakeholders to work jointly toward efficient, affordable, resilient, and healthy space cooling such as in the Climate and Clean Air Coalition, Cool Coalition, Clean Cooling Collaborative, Cooling for All, etc.
Planning instruments	• Definition of comprehensive implementation pathways and coordinated actions to deliver space cooling comfort at all levels (national, regional, local) • Countries commit to transition to climate friendly, health-promoting, resilient, and efficient space cooling solutions • Cities to develop heat action plans	• Governments to develop and implement National Cooling Strategies compatible with international best practices and to include space cooling in energy strategy and plans
		• Governments to include space cooling in Nationally Determined Contributions (NDCs)
		• Enforce integrated urban planning and urban energy planning methodologies, which also integrate inclusive expansion of green and blue space and district cooling into the urban planning process
		• Develop best practices for heat action plans; implement such plans at the local level, including issuing heat warnings and opening public cooling centres
Education and training	• The consumer is encouraged to buy high-efficiency over low-efficiency space cooling equipment • The consumer is encouraged to participate in flexibility programmes • The consumer is encouraged to utilise ancillary service demand reduction measures • The consumer is encouraged to use the equipment parsimoniously • Designers are encouraged to promote high-efficiency and climate friendly space cooling equipment over lower efficiency equipment • Designers are up-to-date with the best practices and are skilled to match the equipment size to the needs • Installers can ensure proper operation and minimise refrigerant leakages	• Awareness campaigns and behavioural change programmes to inform people about existing regulations, active and passive space cooling options, and space cooling best practices through a set of communication tools
		• Governments to deliver proper training and knowledge to the different stakeholders
		• Governments to mandate space cooling equipment product labelling and encourage zero-carbon-ready building certifications

A win-win for climate and health

The rapid growth of AC is putting stress on the power grid, whilst exacerbating the adverse impact of space cooling on GHG emissions, local air pollution, power outages, urban heat island effects, energy poverty, and physiological acclimatisation. Demand for cooling is projected to be the second-largest contributor to the overall rise in global electricity demand over the coming decades, behind electric vehicles, and should therefore be a focus for policy makers.

The technical and policy response measures outlined in Tables 1 and 2 are a win-win: they can ensure that lower income households are not left behind and that growth in space cooling does not cause harm to the climate and health. Technical, organisational, and policy responses, such as those outlined above, can unlock the opportunity to ensure affordable access to cooling for everyone in the world who needs it, in a sustainable way, thus minimising the harms of AC usage and saving tens of thousands of lives each year.

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